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- V. "On the Mode in which Sonorous Undulations are conducted from the Membrana Tympani to the Labyrinth, in the Human Ear." By JOSEPH TOYNBEE, Esq., F.R.S. &c. Received May 24, 1859.

The opinion usually entertained by physiologists is that two channels are requisite for the transmission of sonorous undulations from the membrana tympani to the labyrinth, viz. the air in the tympanic cavity which transmits the undulations to the membrane of the fenestra rotunda and the cochlea; and secondly, the chain of ossicles which conduct them to the vestibule.

This opinion is, however, far from being universally received; thus, one writer on the Physiology of Hearing contends that "the integrity of one fenestra may suffice for the exercise of hearing*," another expresses his conviction that "the transmission of sound cannot take place through the ossicula†;" while Sir John Herschel, in speaking of the ossicles, says "they are so far from being essential to hearing, that when the tympanum is destroyed and the chain in consequence hangs loose, deafness does not follow‡."

The object of this paper is to decide by experiment how far the ossicles are requisite for the performance of the function of hearing.

The subject is considered under two heads, viz.—

1. Whether sonorous undulations from the external meatus can reach the labyrinth without having the ossicles for a medium.
2. Whether any peculiarity in the conformation of the chain of ossicles precludes the passage of sonorous undulations through it.

1. *Can sonorous undulations reach the labyrinth from the external meatus without the aid of the ossicles?*

This question has often been answered in the affirmative, apparently because it has been ascertained that in cases where two bones of the chain of ossicles have been removed by disease, the hearing power is but slightly diminished. In opposition to this view, it must, however, be remembered, that the absence of the stapes, or even its fixed condition (ankylosis), is always followed by total or

* Mr. Wharton Jones, *Cyclopædia of Surgery*, Art. "Diseases of the Ear," p. 23.

† *Lancet*, 1843, p. 380.

‡ *Encyclopædia Metropolitana*, Art. "Sound," p. 810.

nearly total deafness ; and the following experiments, which demonstrate the great facility with which sonorous undulations pass from the air to a solid body, indicate that the stapes, even when isolated from the other bones of the chain, may still be a medium for the transmission of sound.

Experiment 1.—Both ears having been closed, a piece of wood, 5 inches long and half an inch in diameter, was held between the teeth, and a vibrating tuning-fork C' having been brought within the eighth of an inch of its free extremity, the sound was heard distinctly, and it continued to be heard between five and six seconds.

Experiment 2.—One end of the piece of wood used in the previous experiment being pressed against the tragus of the outer ear, so as to close the external meatus without compressing the air contained within it, a vibrating tuning-fork C' placed within a quarter of an inch of its free extremity, was heard very distinctly at first, and it did not cease to be heard for fifteen seconds.

Experiment 3.—Three portions of wood, of the same length and thickness as that used in the previous experiments, were glued together so as to form a triangle somewhat of the shape of the stapes ; the base of this triangle being placed against the outer surface of the tragus, as in the previous experiment, the tuning-fork C' vibrating within a quarter of an inch from its apex was heard for twelve seconds.

Considering, as shown by the above experiments, the great facility with which sonorous undulations pass from the air to a solid body, it may, I think, be assumed that the undulations in the tympanic cavity may be conveyed to the stapes even when this bone is isolated from the rest of the chain, and conducted by it to the vestibule ; and when it is also considered that the absence of all the ossicles, or even a fixed condition of the stapes, is productive of deafness, there is strong evidence in favour of the opinion that *sounds from the external meatus cannot reach the labyrinth without the medium of the ossicles.*

2. *Is there any peculiarity in the conformation of the chain of ossicles which precludes the passage of sonorous undulations through it ?*

This question has also been answered in the affirmative, on account of the various planes existing in the chain ; and secondly, on account of the joints existing between the several bones composing this chain.

The following experiments refer to the influence of the varying plane of the bones forming the chain, and of its articulations, on the progress of sonorous undulations through it:—

I. *Experiments illustrative of the influence of the variety of planes in the chain.*

Experiment 1.—Three pieces of wood, each 5 inches in length and half an inch thick, were glued together thus , so as to represent the planes in which the malleus, incus, and stapes are arranged in the chain of ossicles, while three similar portions were glued end to end so as to form a straight rod. A watch was placed in contact with one end of the straight rod, while the other was pressed gently against the tragus so as to shut the external meatus. The result was that the watch was heard nearly as distinctly as when in contact with the ear. When a similar experiment was performed with the angular portion of wood representing the chain of bones, the watch was also heard, but less distinctly than through the straight portion.

Experiment 2.—A tuning-fork C', being made to vibrate, was placed in contact with one extremity of the angular piece of wood, the other being placed against the tragus of the ear; and as soon as the sound ceased to be heard, the straight portion was substituted, when the tuning-fork was again heard, and it continued to be heard for about three seconds.

Experiment 3.—A vibrating tuning-fork C' was placed at one extremity of the angular piece of wood, the other extremity being held between the teeth; the fork was at first heard very distinctly, and when its sound could no longer be distinguished, the straight piece was substituted, and it was again heard for the space of two seconds.

Experiment 4.—Instead of the horizontal portion of wood representing the stapes, three portions of the same size were made into a triangle, and this was glued to the anterior surface of the inferior extremity of the piece representing the incus, thus . The previous experiment was then repeated with the substitution of this apparatus for the angular one, and with nearly the same result, viz. the fork was heard through the straight piece about three seconds

after it had ceased to be heard by the apparatus representing the chain of bones.

Experiment 5.—A piece of very thin paper was gummed over the end of a glass tube 6 inches in diameter; to the outer surface of this paper was glued a model of the chain of ossicles similar to the one used in the previous experiment; a vibrating tuning-fork C' being placed in the interior of the tube and within a quarter of an inch of the paper, the sound was heard through the free end of the chain placed between the teeth for ten seconds; when the sound ceased to be heard, a straight piece of wood was substituted, and the sound was not heard through it.

II. *Experiments illustrative of the influence of the articulations in the chain.*

Experiment 1.—Three pieces of wood, each about 5 inches long and half an inch in thickness, were separated from each other by pieces of india-rubber as thick as ordinary writing-paper, and they were then fastened together so as to assume the angular form possessed by the chain of ossicles. The tuning-fork C' being placed at the free extremity of the chain, the other extremity being held between the teeth, it was found that the sound was heard as distinctly and for the same length of time, as when it passed through the chain formed of three portions glued together.

Experiment 2.—When eight layers of the india-rubber were placed between each piece of wood, there was still very little difference in the intensity of the sound from that observed when it passed through the portions glued together.

Experiment 3.—One, two, or three fingers having been placed between the first and second pieces of wood, and eight layers of india-rubber between the second and third, a very slight diminution in the intensity and duration of the sound was observed as compared with its passage through similar pieces when glued together.

Experiment 4.—The back of the hand was placed in contact with the teeth, and the end of the vibrating fork C' was pressed against the palm; the sound was heard very distinctly for several seconds; and when it ceased to be heard, a piece of solid wood 3 inches long was substituted, through which the sound of the fork was again heard faintly for four seconds.

The inference from the two series of experiments above detailed is,

that neither the variation of the plane existing in the chain of ossicles, nor the presence of the articulations, is sufficient to prevent the progress of sonorous undulations through this chain to the vestibule.

The experiments and observations detailed above lead to the following conclusions :—

1. That the commonly received opinion in favour of the sonorous undulations passing to the vestibule through the chain of ossicles is correct.
2. That the stapes, when disconnected from the incus, can still conduct sonorous undulations to the vestibule from the air.
3. So far as our present experience extends, it appears that in the human ear sound always travels to the labyrinth through two media, viz. through the air in the tympanic cavity to the cochlea, and through one or more of the ossicles to the vestibule.

VI. “On the Electrical Discharge *in vacuo* with an Extended Series of the Voltaic Battery.” By JOHN P. GASSIOT, Esq., V.P.R.S. Received May 24, 1859.

In a recent communication, since ordered for publication in the Philosophical Transactions, I described some experiments on the electrical discharge in a vacuum obtained by the absorption of carbonic acid with caustic potassa, and I showed that, when the discharge from an induction coil was passed through such a vacuum, the stratifications became altered in character and appearance as the potassa was more or less heated. I have also in a former paper (Phil. Trans. 1858, p. 1) shown that the stratified discharge can be obtained from the electrical machine.

A description of an extended series of a water-battery was communicated by me as far back as December 1843 (Phil. Trans. 1844, p. 39). This battery consists of 3520 insulated cells: some years had elapsed since it was last charged, and I found the zincs were very much oxidated; on again charging it with rain-water, I ascertained that there was sufficient tension to give a constant succession of minute sparks between two copper discs attached to the terminals of the battery, and placed about $\frac{1}{8}$ th of an inch apart. On attaching the terminals of the battery to the wires in a carbonic acid